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# NRC Staff Review of Environmental Models

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Office of Nuclear Regulatory Research
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Office of Nuclear Material Safety and Safeguards

***2016 ISCMEM Annual Public Meeting***
***National Science Foundation, Arlington, VA***
***December 14, 2016***

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# Presentation Outline

- Assess Materials Decommissioning Sites, Uranium Recovery Facilities and High-Level Radioactive Waste Tank Farm Closures
- Input to Probabilistic Consequence Analysis using MACCS
- Assess Hydrologic Hazards such as Floods at Nuclear Power Plant Sites
- Identify Opportunities to Share Models and Databases

# Interagency Steering Committee on Multimedia Environmental Models (ISCMEM)
# December 14, 2016

## Environmental Modeling

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# NRC/NMSS Examples of Environmental Model Reviews

Materials Decommissioning Sites

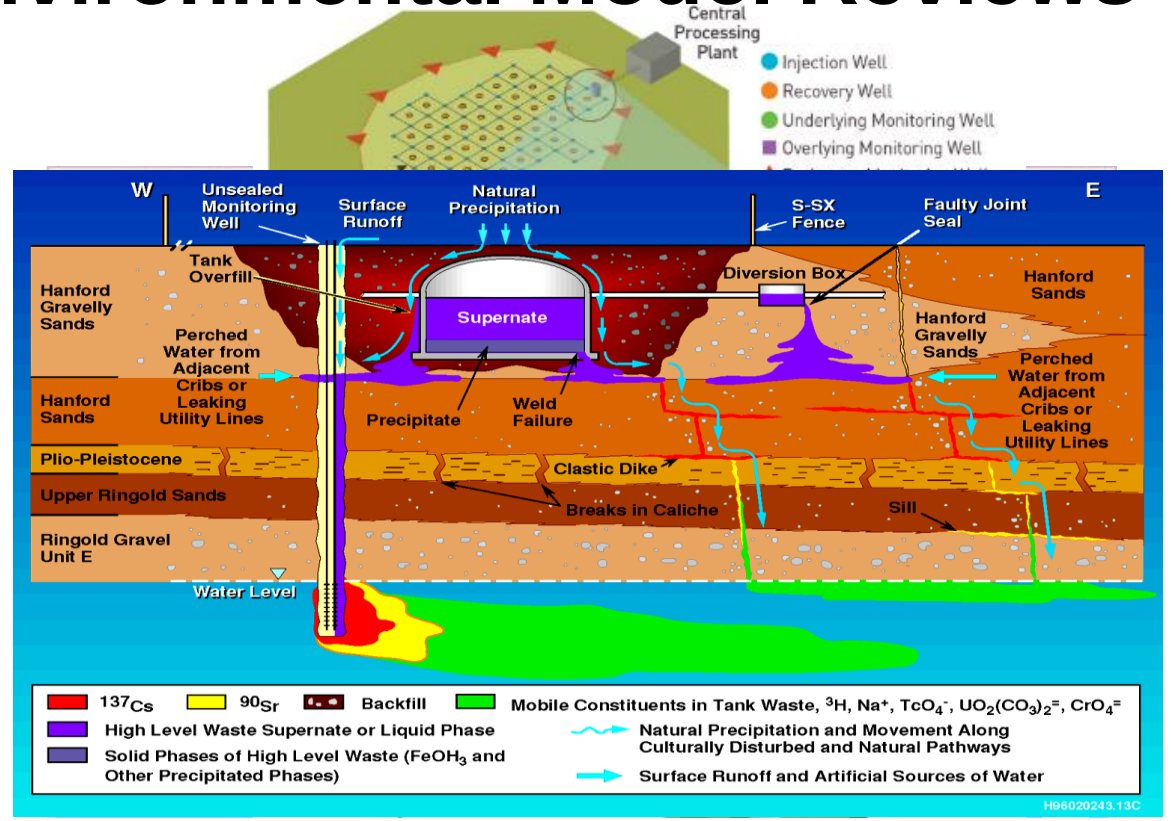
- Sampling plans
- Dose modeling

Uranium Recovery

- Geochemical modeling
- Flow and transport

DOE Tank Farm Closure Activities

- Infiltration and erosion control
- Geochemical modeling
- Flow and transport
- Probabilistic simulations




HLW Tank Farm Conceptual Model

*(Caggiano JA. 1996. Assessment Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area S-SX. WHC-SD-EN-AP-191, Westinghouse Hanford Company, Richland, Washington.)*

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# NRC/NMSS Independent Environmental Modeling

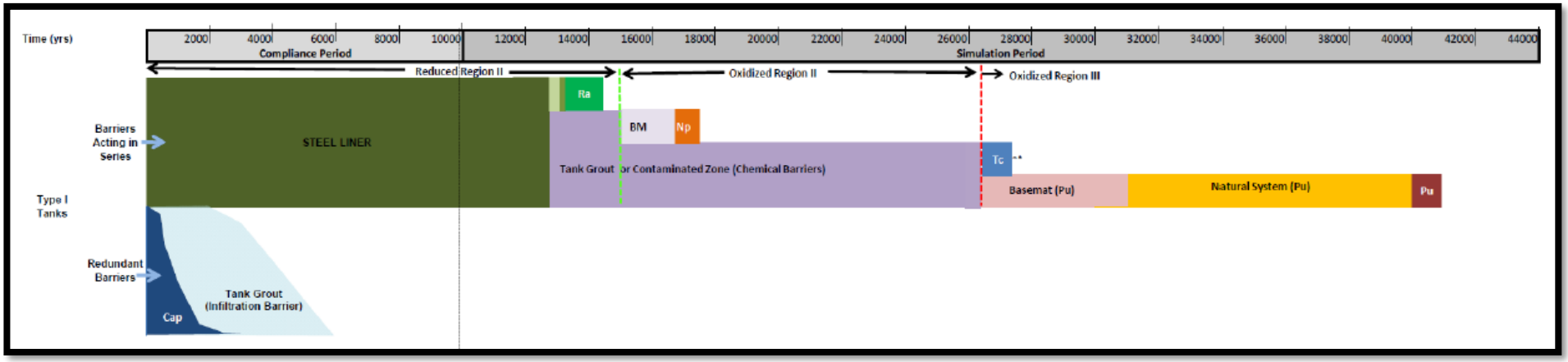
Improve understanding through additional analyses

- Sensitivity analyses
- Uncertainty analyses
- Barrier analyses

Risk-inform the performance assessment review

Identify critical issues in complex systems

Expedite the review




**Barrier Analysis - F Tank Farm DOE Savannah River Site**
(Adapted from Figure 3-5 Combined F and H Tank Farm Monitoring Plan, ML15238A761)

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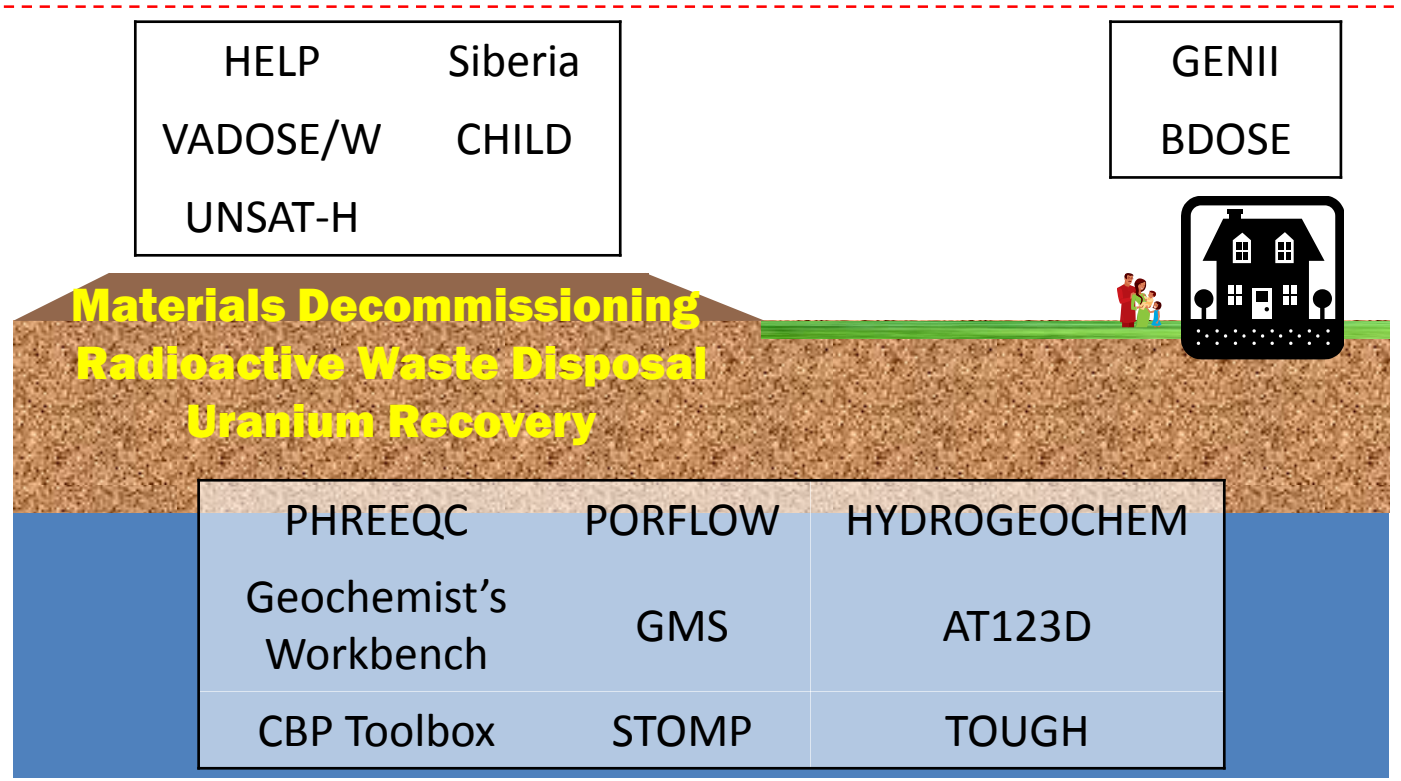
# Environmental Models and Computational Tools

RESRAD D&D GoldSim

HELP Siberia
VADOSE/W CHILD
UNSAT-H

GENII
BDOSE




ArcGIS SADA Neuralworks

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# Environmental Modeling Challenges and Opportunities

## Challenges

- Conceptual model uncertainty
- Data versus model limitations
- Verification & “Validation”
- Model support
- Training

## Opportunities

- Lessons learned
- Environmental model and data sharing
- Compendium of data
- Development of databases

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# Probabilistic Consequence Analysis using MACCS

*Dr. Keith L. Compton*

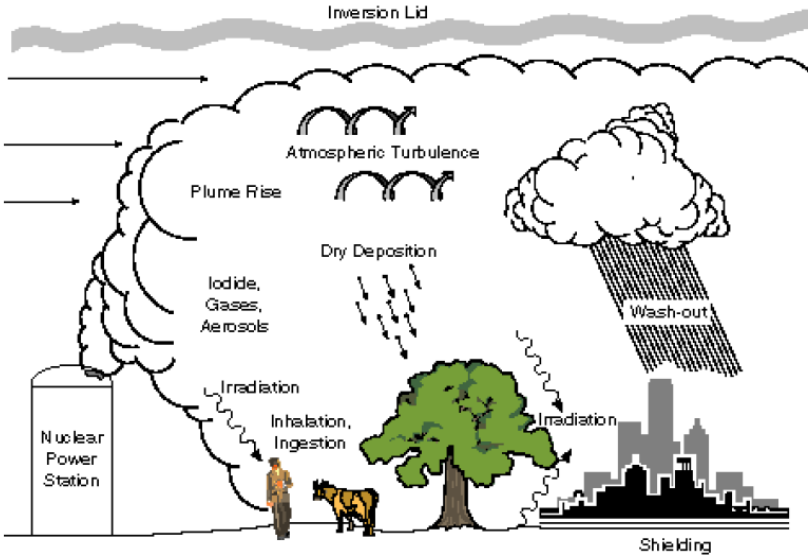
*U.S. NRC Office of Nuclear Regulatory Research*

*Interagency Steering Committee on Multimedia Environmental Models (ISCMEM)*

*December 14, 2016*

# Overview of Severe Accident Consequence Analysis

- Probabilistic consequence analysis focuses on developing realistic estimates of the consequences of a full range of potential accidents
- Prospective analysis: must consider a range of potential meteorological conditions
- Multiple types of consequences (doses, health effects, economic impacts, etc.) may be of interest
- Typically includes modeling the radioactive release to the atmosphere (e.g. plume rise, dispersion, dry and wet deposition).



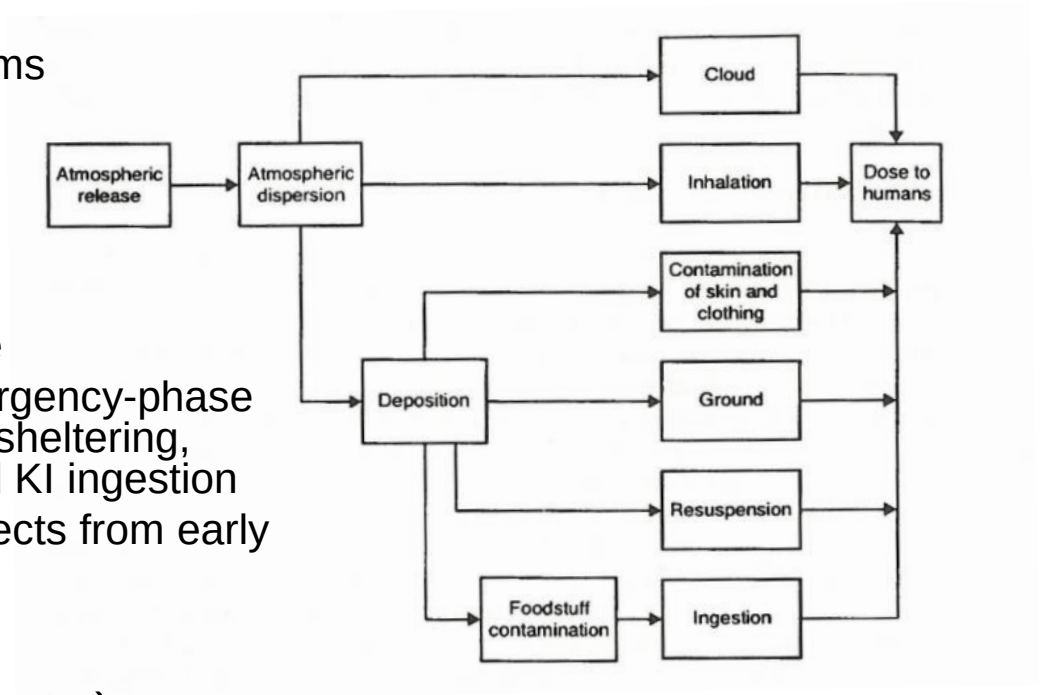

- Direct releases to other media (e.g., unsaturated zone, groundwater, surface waters, etc.) have typically not been included in severe accident consequence analyses.

# Severe Accident Consequence Analysis: MACCS Applications

| | Risk-Informed Decision-making | Backfit Analysis | Reg. Analysis | SAMA/ SAMDA | Envir. Assmt. | Level 3 PRA | Research Studies |
|---|---|---|---|---|---|---|---|
| | RG 1.174 | NUREG-1409 | NUREG/ BR-0184 | NUREG-1555 | NUREG-1555 | | |
| Individual Early Fatality Risk | X | X | X | X | X | As specified | As specified |
| Individual Latent Fatality Risk | X | X | X | X | X | | |
| Collective Dose Risk | | X | X | X | X | | |
| Offsite Property Damage Risk | | | X | X | X | | |
| Total Early Fatality Risk | | | | | X | | |
| Total Latent Fatality Risk | | | | | X | | |
| Land Contamination Risk | | | | | X | | |

# MACCS Modules

- ATMOS
  - Source term definition
  - Weather sampling algorithms
  - Atmospheric transport, dispersion, and deposition




- EARLY (1 day to ~1 week)
  - Includes emergency phase
  - Doses as modified by emergency-phase countermeasures such as sheltering, evacuation, relocation, and KI ingestion
  - Acute and latent health effects from early acute exposure

- CHRONC (~1 week to >50 years)
  - Includes both intermediate and long term recovery phases
  - Doses as modified by long-term protective actions such as decontamination, interdiction, and condemnation
  - Latent health effects from chronic exposure to deposited materal
  - Economic impact from early and late phase protective actions

# MACCS Preprocessors

- MELMACCS
  - Utility for creating a MACCS formatted source term from MELCOR
- SECPOP
  - US site specific population distribution and economic parameters based on US census and economic databases
- Dose Conversion Factor utility codes and files
  - DOSFAC2 code
  - FGRDCF code
  - ICRP-68/72 file
- COMIDA/COMIDA2 code
  - Food chain
  - Includes decay and ingrowth
  - A standard file is distributed with MACCS/WinMACCS

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# *Freshwater Transport of Radionuclides*

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*December 14, 2016*

*Dr. Mark Fuhrmann*

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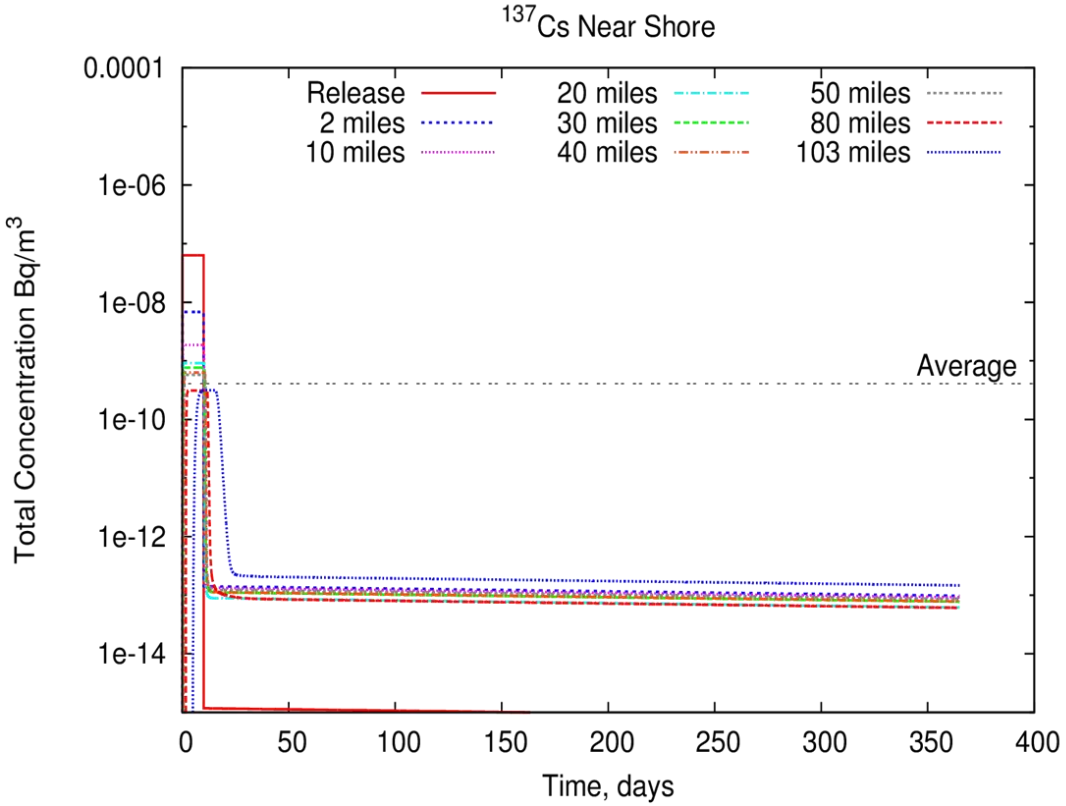
NRC contracted PNNL to model contaminant flow in a Large River, a Small River and a Small Lake.
Report to be published as NUREG/CR-7231




MASS2 and TETHYS Models were used, producing very detailed results.

Massively Parallel computing system was needed.

Large amount of bathymetry data was needed.

# Modeling of Surface-Water Transport of Radionuclides

- NRC staff is interested in simple models of contaminant transport in rivers and lakes
  - Areas specific to nuclear power plants
  - May need long stretches of rivers; pulse can travel hundreds of miles with relatively little dilution
  - Need input from tributaries
  - Sediment interactions
- Suggestions?

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# Hydrologic Hazard Modeling

***Dr. Meredith Carr***
***US NRC Office of Nuclear Regulatory Research***

- External hazards (e.g., floods) from the environment pose a safety concern. Models and tools are used to assess and prepare for these risks
  - Review of submitted hydrologic hazard assessments (confirmatory modeling)
    - New reactor license applications
    - Operating reactor license amendment requests
    - Risk assessment of inspection findings, deficiencies, unusual events, etc.
    - Post-Fukushima flooding re-evaluations
  - Research to support regulatory guidance development

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# Hydrologic Hazard Modeling

- Tools
  - Used by NRC staff and contractors for hydrologic hazard modeling

Flood Frequency Analysis Models

HEC-SSP

PeakFQ

Scientific and Statistical Toolboxes

R (Statistical Package)

Matlab

Surface Water Models,

HEC-HMS

HEC-RAS

Flow 2D

ADCIRC

SLOSH

DELFT3D

NEUTRINO

MASS2

Numerical Weather Models

WRF

Reanalysis Models

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# Hydrologic and Hydraulic Models

- HEC-HMS, HEC-RAS, Flow 2D used in support of Flood Hazard Assessments

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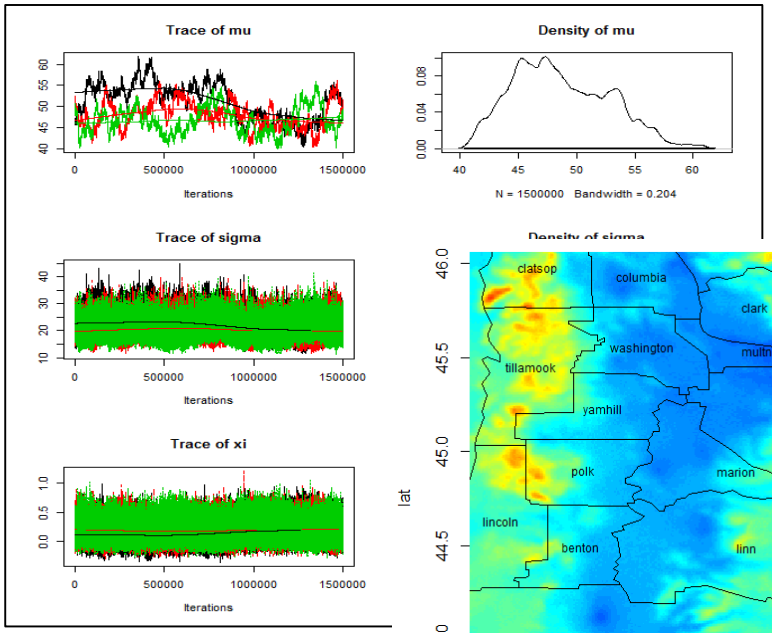
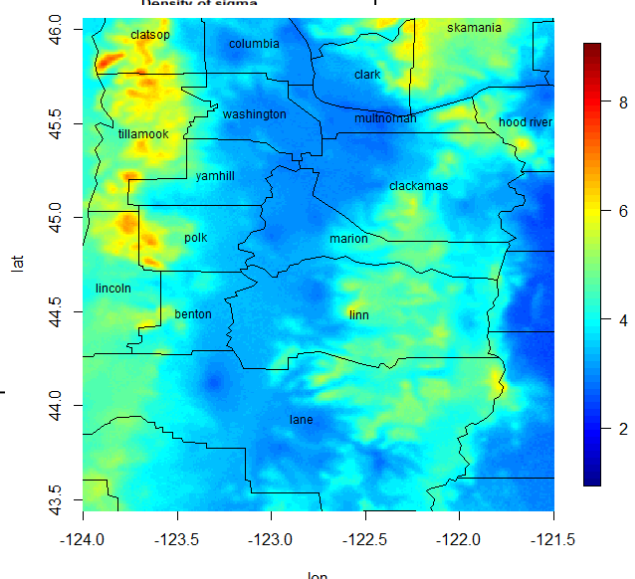
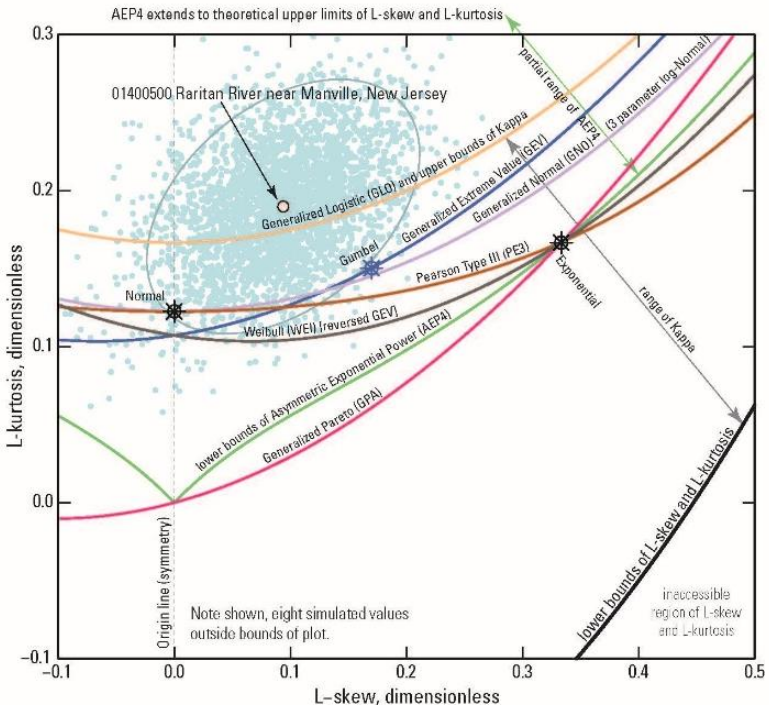
# Flood Frequency Modeling

- Multiple Projects, R Programming Language and Software Environment
- Trace and density plots of the GEV model distribution parameters resulting from three MCMC runs
- Return Period Maps using a model dependent on 4 parameters

L- Moment Diagram to assess fits of multiple distribution to systematic data record and simulated values based on variance-covariance



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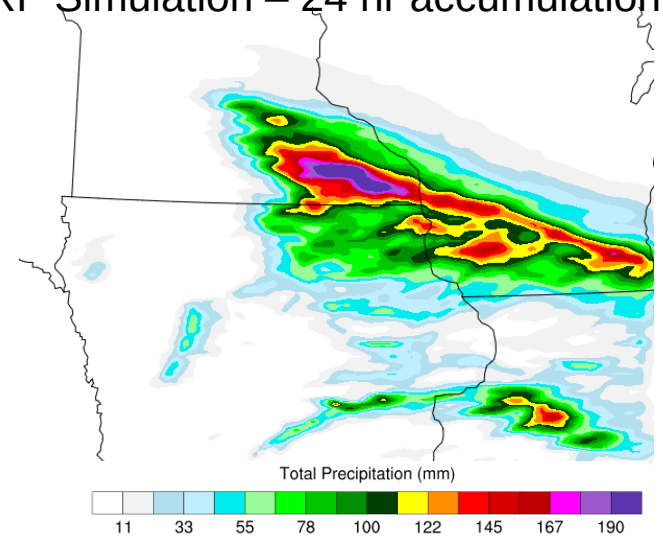
# Local Intense Precipitation Processes Modeling

- USGS/UC Davis
- Assess capability of regional numerical weather simulation models (WRF) to accurately simulate extreme precipitation events
- Use models to investigate impact of climate change on extreme precipitation events
  - Benchmark simulation and validation of select intense storms
  - Simulation of selected intense storms in observational record and analysis of underlying processes responsible for intense precipitation

WRF Simulation – 24 hr accumulation




Mesoscale Convective System (MCS) for August 19, 2007 event

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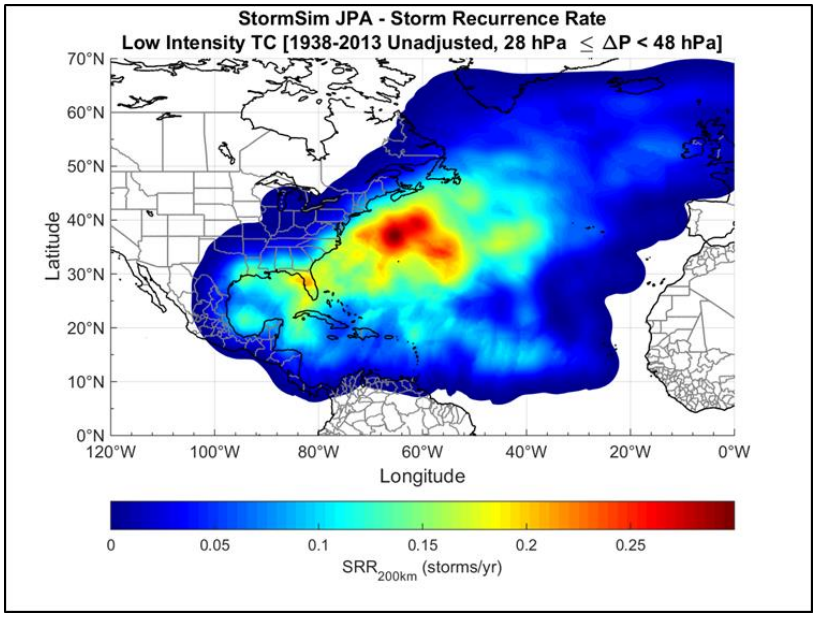
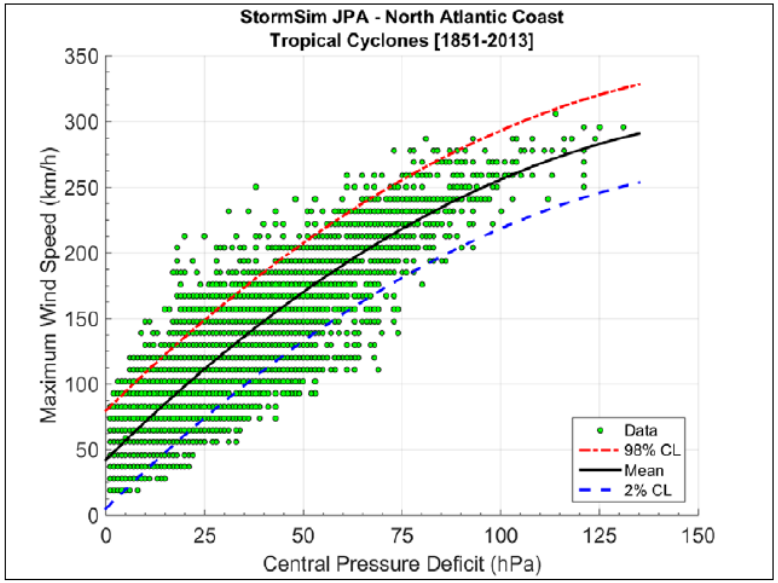
# Quantifying Uncertainties in Probabilistic Storm Surge Models

- USACE
- Numerical simulations using the ADCIRC model
- Quantify epistemic and aleatory uncertainties inherent in the key steps of probabilistic storm surge modeling
  - Storm recurrence rate (SRR) models
  - Characterization of storm climatology and probability distributions of storm parameters
  - Discretization of probability distributions and generation of synthetic storms
- Investigate the propagation of uncertainties in joint probability analyses of storm surge hazard



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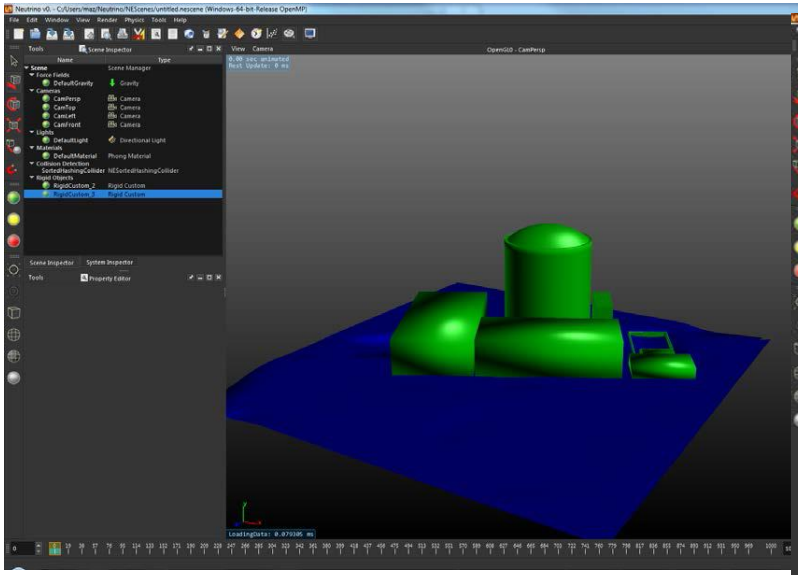
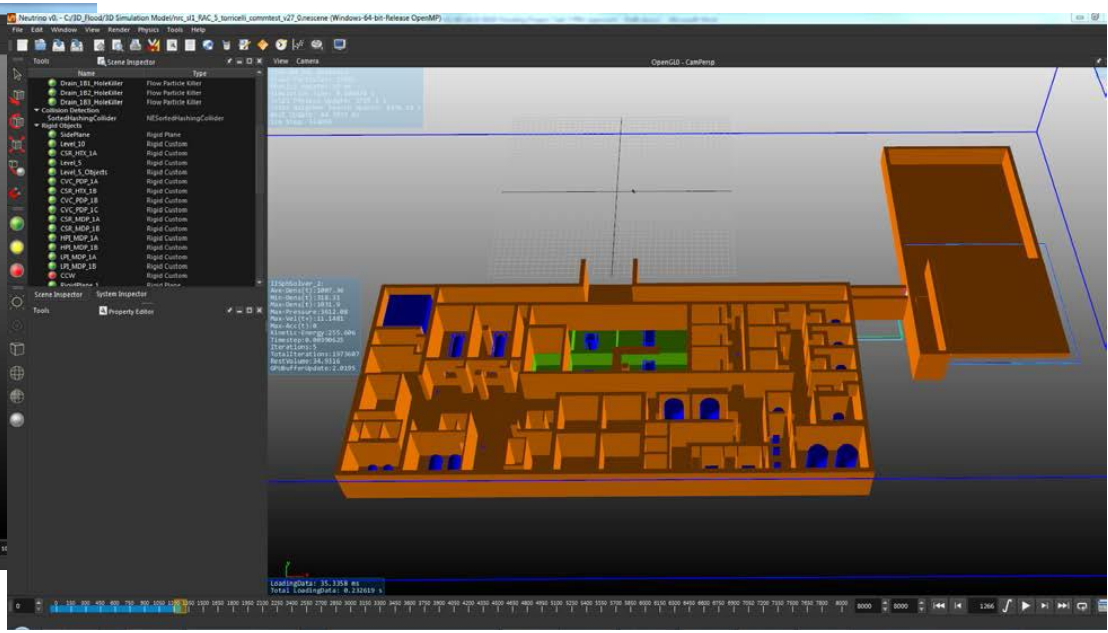
# 3D Smooth Particle Hydrodynamics for Modeling Flooding in a Plant

- INL
- 3D simulation models were developed using the 3D simulation software Neutrino to simulate the flooding scenarios and communicate with the PRA model
- A 3D site terrain model was obtained for the interested plant/site with a web-based application that interacts with the Google Elevation API
- A typical 3D plant model was also developed. Flooding scenarios and pathways were identified





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# Radiation Protection Code Analysis and Maintenance Program (RAMP)

*Interagency Steering Committee on Multimedia Environmental Models (ISCMEM)*

*December 14, 2016*

*John J. Tomon*

*US NRC Office of Nuclear Regulatory Research*

*RAMP@nrc.gov*

# RAMP

**RAMP** is part of the NRC's cooperative research program which supports the development and maintenance of radiation/dose assessment codes and provides in-depth services to RAMP members.

- Over 400 RAMP members including the NRC, other Federal and State Agencies, Licensees and Vendors & 10 International Agreements
- Membership is free for Federal and State Agencies
- RAMP Annual User Meetings (Domestic and International)
- More efficient use of resources (leverages group dynamics) to update dosimetry, source terms and state-of-the-art modeling in all the codes
- RAMP webpages for each code (https://www.usnrc-ramp.com/)
  - User Forums & Technical Support
  - Technical Documentation including Benchmarking Studies
  - Online Training Modules & Presentations

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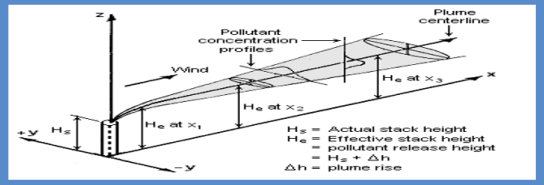
# Dose Assessment Codes in RAMP

## Environmental


**MILDOS 4**

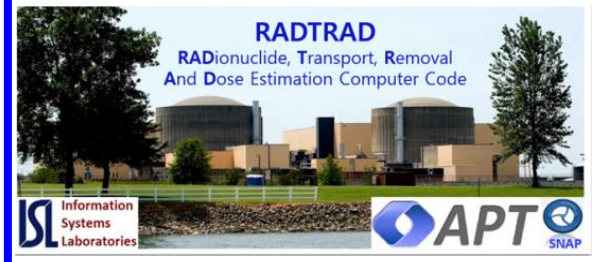
Radiological Dose from Uranium Milling


Atmospheric Codes




PAVAN ARCON96 XOQ/DOQ

## NPP Licensing




Gaseous And Liquid Effluent

Habit 2.0

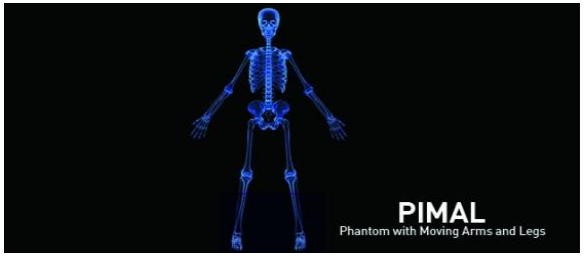
## Emergency Response Code


## Other Dose Assessment Codes

V5 varskin

VARSKIN
Computer Code for Skin Contamination Dosimetry

RADIOLOGICAL TOOLBOX



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# Summary

- Codes used by the NRC staff provide useful tools for assessing environmental consequences involving flood risks and radionuclide releases and transport in air, soil, surface- and ground-water systems
- NRC staff is pursuing enhancement of environmental models and databases for a variety of regulatory applications, particularly for air transport modeling
- NRC staff looks forward to cooperating with other Federal Agencies, universities and users of the environmental models in the ISCMEM work groups

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# Information Sources

ArcGIS www.arcgis.com
AT123D http://www.seview.com/aboutat123d.htm
BDOSE http://pbadupws.nrc.gov/docs/ML1107/ML110750358.pdf
CBP Toolbox http://cementbarriers.org/
CHILD https://csdms.colorado.edu/wiki/Model:CHILD
DandD https://www.usnrc-ramp.com/DandD
Geochemist's Workbench https://www.gwb.com/
GENII http://energy.gov/ehss/genii
GMS http://www.aquaveo.com/
GoldSim http://www.goldsim.com/Home/
HELP https://www3.epa.gov/
HYDROGEOCHEM http://www.scisoftware.com
Neuralworks http://www.neuralware.com/

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# Information Sources (continued)

PHREEQC http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/
PORFLOW http://www.acricfd.com/software/porflow/
RESRAD http://www.evs.anl.gov/resrad/
SADA http://www.sadaproject.net/
Siberia http://www.telluricresearch.com/siberia-homepage.html
STOMP http://stomp.pnnl.gov/
TOUGH http://esd1.lbl.gov/research/projects/tough/
UNSAT-H http://hydrology.pnnl.gov/resources/unsath/unsath.asp
Vadose/W https://www.geo-slope.com/products/vadose-w